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CENIZA-ARENA CLEANUP IN SAN JOSE, COSTA RICA: OPERATIONAL ASPECTS AS RELATED TO NUCLEAR WEAPON FALLOUT DECONTAMINATION

AD617143

CONTRACT NO. N228-(62479)65421
OCD SUBTASK NO. 3231C

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

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May 1963

CENIZA-ARENA CLEANUP IN SAN JOSE, COSTA RICA: OPERATIONAL ASPECTS AS RELATED TO NUCLEAR WEAPON FALLOUT DECONTAMINATION

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SRI Project MU-5069

CONTRACT NO. N228-(62479)65421
OCD SUBTASK NO. 3231C

Prepared for:

OFFICE OF CIVIL DEFENSE
DEPARTMENT OF THE ARMY
WASHINGTON D.C. 20310

Through:

TECHNICAL MANAGEMENT OFFICE
U.S.N.R.D.L.
SAN FRANCISCO, CALIFORNIA 94135

This report has been reviewed in the Office of Civil Defense Department of the Army, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

ABSTRACT

The continuing eruptions of Volcán Irazú and the consequent deposition of volcanic debris on the city of San José, Costa Rica, offered a unique opportunity to improve our understanding of the physical effects of fallout-like particles (ceniza-arena) deposited in urban areas. Detailed records of ceniza-arena deposition and removal from San José were tabulated and analyzed. The magnitude and problems of decontaminating a fallout contaminated city were illustrated (except for the complicacy of radiation) in the San José ceniza-arena cleanup operations.

ACKNOWLEDGMENT

The authors wish to acknowledge the generous assistance of the following people during their visit to San José, Costa Rica, August 16-30, 1964:

Lt. Col. Virgil Cordero, U.S. Military Mission to Costa Rica, for introductions to municipal personnel.

Señor Guilliam Castro E., Governor of the Province and Mayor of the city of San José, Costa Rica, for discussing the political aspects of the ceniza-arena cleanup problem and giving permission to use the municipal records.

Señors Ing. Manual A. Padilla J. and Alvaro Gómez A., for furnishing and explaining the detailed records that are a vital part of this report and for showing the authors all phases of the ceniza-arena removal operations.

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I INTRODUCTION

The continuing eruptions of Volcán Irazú and the consequent deposition of volcanic debris on the city of San José, Costa Rica, offer a unique opportunity to improve our understanding of the physical effects of falloutlike particles deposited in urban areas. The volcanic particles (ceniza-arena)* have physical properties similar to those of radioactive fallout collected at weapon tests. In addition, the introduction of the volcanic particles into the atmosphere in a rapidly rising air column topped with a mushroom cloud is similar to the introduction of nuclear device and environmental debris into the atmosphere by nuclear explosions. The same meteorological factors involved in the fallout distribution process are present in both cases. The volcanic cloud at times resembles a 5- to 10-KT nuclear explosion, a scale unachieved by usual fallout research simulations. Although the continuous production of the volcanic particles and their distribution by an ever changing meteorological environment produce measurable but unpredictable distributions by size of particles at locations throughout the fallout pattern, the deposits in the city provide a continuing opportunity for the study of large scale operational aspects of decontamination.

The series of eruptions of Volcán Irazú that started in March of 1963 has continued, except for brief dormant periods of at most several days. The eruptions produce no lava flow outside the crater, but large quantities of ceniza-arena particles are ejected to varying heights above the crater and dispersed by the wind. A small fraction of this material is deposited on the city of San José, which lies 15 miles west of the crater along the path of the prevailing easterly winds. Gross estimates of the amount deposited in the city are given in Table 1. These estimates are based on data furnished by the San José Department of Sanitation that summarize the quantities of ceniza-arena hauled to dumps outside the city. The quantities given show the magnitude of the city decontamination, or cleanup, problem. For reasons to be discussed later, the cumulative (since April 30, 1964) haulage figures for 0.66 square mile of downtown area have exceeded the measured ceniza-arena deposit (at one location in the city) by a factor of 7. Between April

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* Ash-sand, coined native descriptive terminology, also commonly referred to as ceniza.

Table 1

CENIZA-ARENA HAULAGE BY MONTH
April 1, 1963, to August 10, 1964

Month	Cubic Meters	Tons*	Cumulative Tons
April 1963	562	992	992
May	1,484	2,621	3,613
June	1,084	1,914	5,527
July	848	1,498	7,025
August	506	894	7,919
September	0	0	7,919
October	0	0	7,919
November	130	230	8,149
December	13,229	23,360	31,509
January 1964	17,287	30,530	62,039
February	15,548	27,460	89,499
March	8,562	15,120	104,619
April	10,291	18,170	122,789
May	10,500	18,540	141,329
June	2,649	4,678	146,007
July	2,750	4,857	150,864
August 1-10	997	1,761	152,625
Total	86,427	152,625	

* Based on ceniza-arena density of 100 lb/ft^3 or 1.76 $tons/m^3$.

Source: Stanford Research Institute; based on data from the San José Department of Sanitation.

30 and August 20, the cumulative total measured deposit was 670.78 g/ft^2; such a deposit, undisturbed, would have resulted in a layer of particles about 3/16 inch deep. Local variations in the uniformity of the deposit within the city might introduce some differences between the total amount deposited in the city and that deposited at the location of measurement.

It is recognized that the ceniza-arena removal operations in San José required a different planning philosophy than would be required in preattack planning for recovery of undamaged urban areas following a nuclear attack on the United States. The most important difference is the absence of a radiological hazard during the ceniza-arena cleanup operations, obviating consideration of operator and population exposure dosage control. On the other hand, uncertainty about the duration of the eruptions made planning for the magnitude of the cleanup job for San José, including the monetary expenditures needed for the operation, subject to political considerations. The general attitude of the people in classifying the ceniza-arena deposits as a temporary inconvenience delayed the monetary appropriations for procurement of adequate equipment for the cleanup work. As the cleanup problem persisted, the government gradually became convinced of the need for proper equipment, the principal evidence being an accurately documented history of the quantities of ceniza-arena removed by hand methods.

The supervision of the ceniza-arena removal operation initially was assigned to the public relations department. Later it was handled by a civil engineer in the sanitation department who introduced a more systematic cleanup procedure and the documentation that provided data for this report.

As for any national emergency, all sources of equipment were sought and utilized. The debris (ceniza-arena plus trash of all kinds) was hauled to the dump by privately owned trucks, many of which were not dump trucks and were manually loaded and unloaded by shoveling. Later, a completely independent municipal hauling capability was developed through the purchase of new trucks and a scheduled use of trucks from all city departments. The subsequent acquisition of front-end loaders for dump truck loading also speeded up the hauling of the debris, further reducing manpower requirements.

Help from outside the country often was ineffective. For example, a donated airport sweeper was completely unmaneuverable in the narrow streets of Costa Rican cities. In another instance, a donated 1928 model tractor with a truck-loading bucket was delivered in a state of disrepair. These two machines presently are stored in the municipal maintenance yard.

II GENERAL CLEANUP SCHEDULE FOR THE CITY OF SAN JOSE

The present schedule for the cleanup of the metropolitan area of the city of San José was inaugurated on April 30, 1964, when the supervision of the operation was delegated to a civil engineer in the Department of Sanitation. The schedule is well planned and provides optimum cleanup for the environmental conditions using available equipment. Figure 1 is a map (see inside of back cover) showing streets swept and dump locations; the map will be helpful in understanding the different phases of the cleanup described below.

The metropolitan area of San José comprises four central districts (Merced, Carmen, Cathedral, and Hospital) and seven suburban districts (San Pedro, Zapoti, San Francisco, San Sebastian, Hatillo, Mata Redonda, and Uruca). It is bounded on the north by the Torres River and on the south by the Tiribi River. The east and west boundaries are less well defined as the population density gradually decreases outside the central districts. The avenues (avenidas) are numbered from the center of the city, odd numbers to the north and even numbers to the south; streets (calles) are numbered odd to the east and even to the west.

Only 40 percent of the streets of San José are suitable for cleaning with motorized street sweepers; these are marked in Figure 2. The cleanup schedule is determined by the number of available sweepers and the miles of streets that can be swept mechanically. The current schedule is to sweep at night the streets in the downtown district enclosed by Avenues 7 and 8 and Streets 14 and 15. Streets suitable for power sweepers outside the downtown district are swept during the day about once a week. Two sweepers, working eastward from Street 42, cover the area south of Paseo Colon and Central Avenue, and two sweepers, working westward from Street 37, cover the northern region. Outlying areas are swept on a time-available basis within the one-week work cycle.

Thirty-one sweeper dumps have been established in locations that are convenient for the sweepers, do not interfere with traffic, and are easily accessible to dump trucks and loading equipment. The ceniza-arena (and trash) from these dumps ultimately is disposed of at four sites outside the city.

The principal environmental factors affecting the street-cleanup schedule are traffic and vehicle-parking conditions during the day and evening and the almost daily afternoon showers during the rainy season. Motorized sweeping is done in two shifts for a total of 14 hours per day. The downtown area is swept between 11:00 p.m. and 5:00 a.m. when there usually is no rain and traffic is at a minimum. Outlying districts, where traffic is usually light, are swept between 6:00 a.m. and 2:00 p.m. on dry days. Truck loading and hauling is usually carried out from 2:00 p.m. to 9:30 p.m. with intermittent interruptions when local rain showers occur. Manual cleanup operations with broom, shovel, and wheelbarrow are usually done in the morning and utilize a total work force of approximately 100 men.

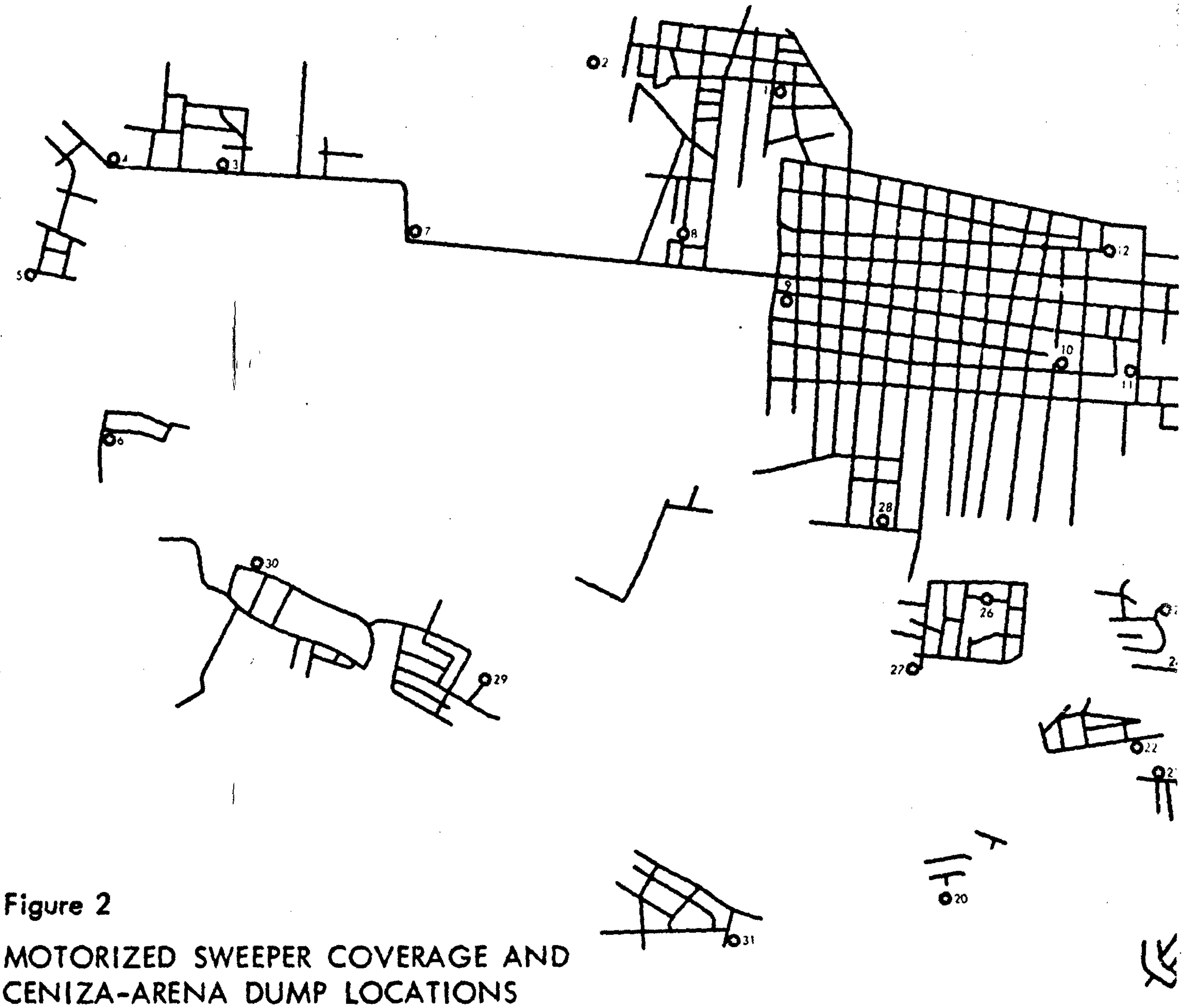
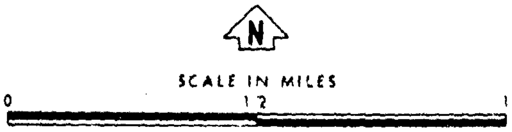
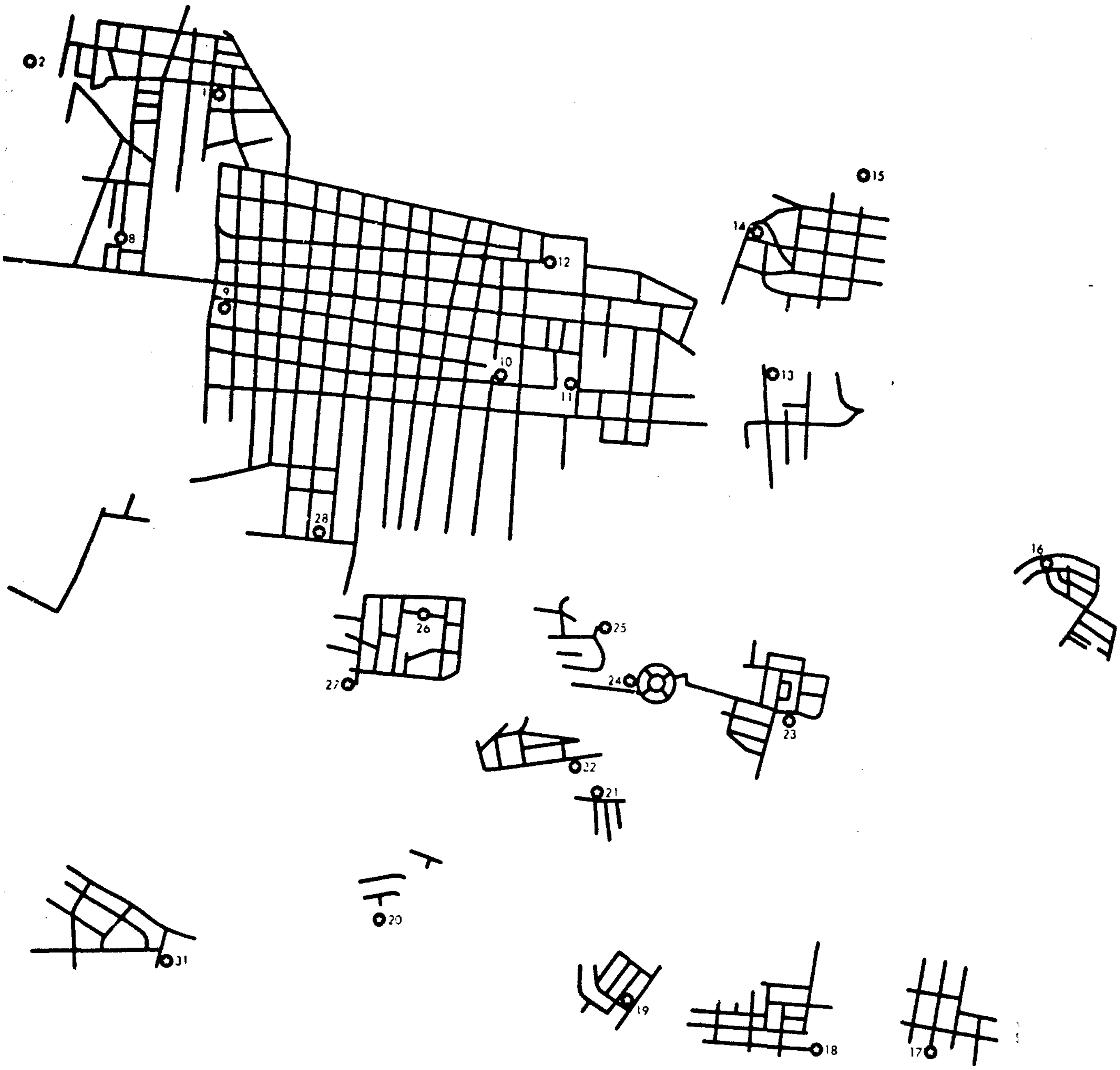


Figure 2

MOTORIZED SWEEPER COVERAGE AND
CENIZA-ARENA DUMP LOCATIONS
IN METROPOLITAN SAN JOSE

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III CLEANUP USING POWER EQUIPMENT

Three types of power equipment are used in San José's ceniza-arena cleanup operation: power sweepers, dump trucks, and front-end loaders. Their usage and fuel consumption are summarized in Table 2.

Table 2

POWER EQUIPMENT USED IN CENIZA-ARENA CLEANUP

Usage and Fuel Consumption

Equipment	Hours per Day per Unit	Fuel Consumption: Gallons per Hour per Unit	Fuel Consumption: Gallons all Units per Day	Number of Operators All Units
Four power sweepers	14	0.59	33	8
Three dump trucks (diesel)	8	0.83	20	3
Four dump trucks (gasoline)	8	2.50	80	4
Two front-end loaders	8	1.00	16	2

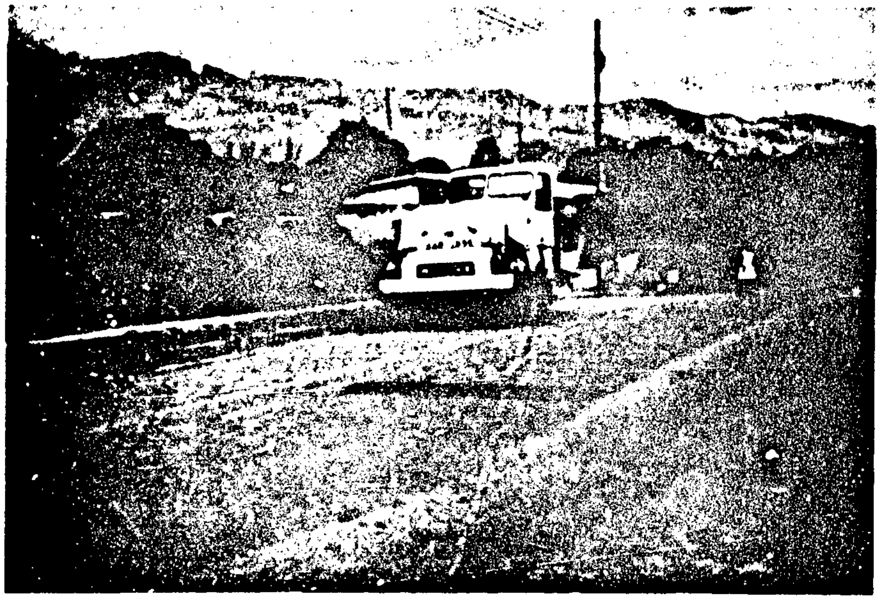
Source: Stanford Research Institute.

Power Sweepers

The city of San José uses four Wayne motorized sweepers (Figure 3) in the general cleanup schedule. They are of the rotating-brush design, and the material swept is carried on a conveyor belt to a front hopper.

Figure 3

MOTORIZED STREET SWEEPING IN SUBURBAN SAN JOSE



Gutter brushes in front, rotating on vertical shafts, serve to sweep gutter deposits into the path of the main brush. A water spray in front is used to minimize the generation of dust clouds by the brooms.

The sweeper manufacturer suggests an operating speed of 5 mph. At this speed, the distance traveled in 14 hours of continuous sweeping would be 70 miles. The quoted mileage for sweeping in the 14-hour work period is 42 miles, or 21 miles of streets along both gutters. Thus the quoted efficiency at which the sweepers are utilized to sweep the area is 60 percent. The reduction of efficiency is due chiefly to time lost in maneuvering around cars parked along the streets, slowdowns because of vehicular traffic, dumping times, and rest periods. This is equivalent to 18 miles of travel per sweeper per six-hour night shift in the downtown area. Actually only 20.3 miles of downtown streets are swept per night, or a little over 5 miles of streets per sweeper. Since both sides of the street were swept (one pass each side) this represents a little over 10 miles of sweeping. The additional loss in efficiency, about 8 miles, is attributed to nonsweeping travel. This includes some overrun of some streets, travel to and from the maintenance yard, and travel to and from the dump sites.

The hoppers are dumped frequently because density of ceniza-arena is higher than the bulk density of trash the sweepers were designed to handle. To prevent overloading on a weight basis, a trash dump level in the hoppers has been established that is well below the normal level, and the operators are instructed not to exceed it. Depending on the amount of deposit, the number of dumps per sweeper per 14-hour working period varies from 4 to 16 (with an average of 10).

Figures 4 and 5 show why 60 percent of the streets cannot be cleaned by a motorized sweeper. Many streets, originally very narrow, have been widened, but the trees and power poles were left in place some distance from the new curbs. These obstacles in the street present a parking problem as well as sweeping difficulties. Unpaved areas between the trees are difficult to clean even by manual methods. Unpaved shoulders, deep gutters, and bridges for access to garages prevent use of motorized sweepers on many streets. Other streets, which might be satisfactory for sweeping in most respects, have holes or uneven pavements that make them unsuitable for sweeping with mechanical sweepers.

The average street in downtown San José is 7 meters wide, which is quite narrow by U.S. standards. Parked cars on both sides, as shown in Figure 6, reduce traffic to a single lane in one direction. On many streets several cars per block are observed to remain parked overnight. These parked cars are obstacles to the efficiency of both the mechanical sweepers and the manual cleanup crews. Legislative attempts to regulate parking so far have proved ineffective and the problem of parked cars persists. Very few streets that otherwise are suitable for mechanical sweeping (see Figure 7) have no parked cars. These streets are in parks or residential areas away from the main business section of the city.

Each sweeper operator cleans the same area each night or each week. He is assigned to a given area with its given dump locations but is free to work out his own pattern of sweeping the assigned area. This mode of operation improves overall efficiency, because each operator attains familiarity with the details and problems in his particular area and has the incentive of working out his own suitable rapid sweeping pattern.

The four sweepers are relatively new, so lost time from equipment breakdown presently is not a factor in the cleanup schedule. Routine maintenance involves only one man; but more complex maintenance, such as changing brushes, requires the labor pool of four mechanics and ten helpers who service all municipal equipment. Refueling is done every other day at the end of the shift between 1:00 p.m. and 2:00 p.m.

Figure 4

TYPICAL SAN JOSE STREET. TREES AND POWER POLES INTERFERE WITH MOTORIZED SWEEPING

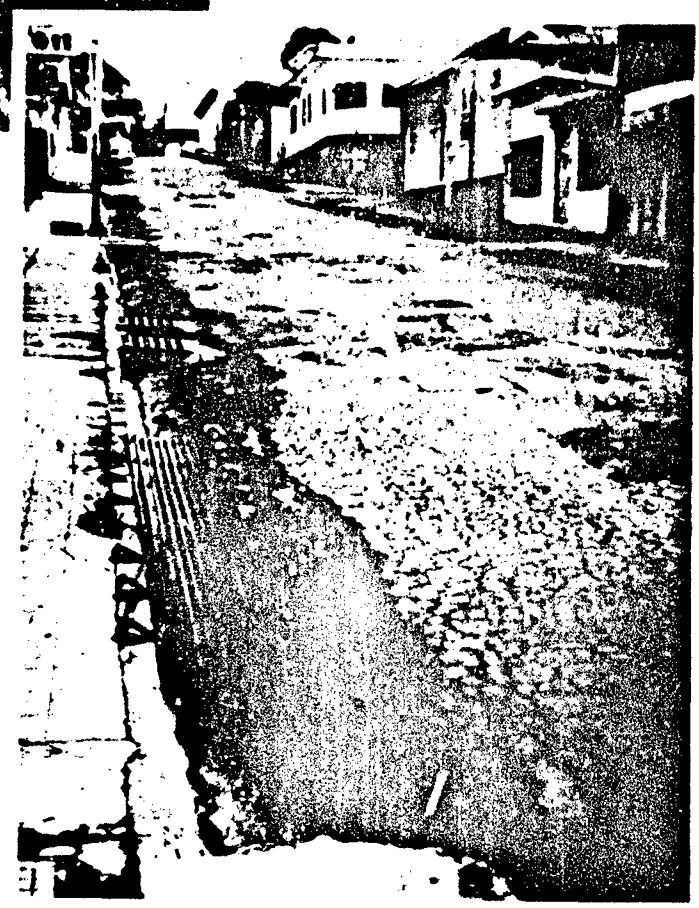


Figure 5

TYPICAL SAN JOSE STREET WITH ROUGH SHOULDER, DEEP GUTTER, AND DRIVEWAY BRIDGES OVER GUTTER

Figure 6

TYPICAL SAN JOSE STREET WHERE MOTORIZED SWEEPING IS IMPOSSIBLE BECAUSE OF PARKED CARS

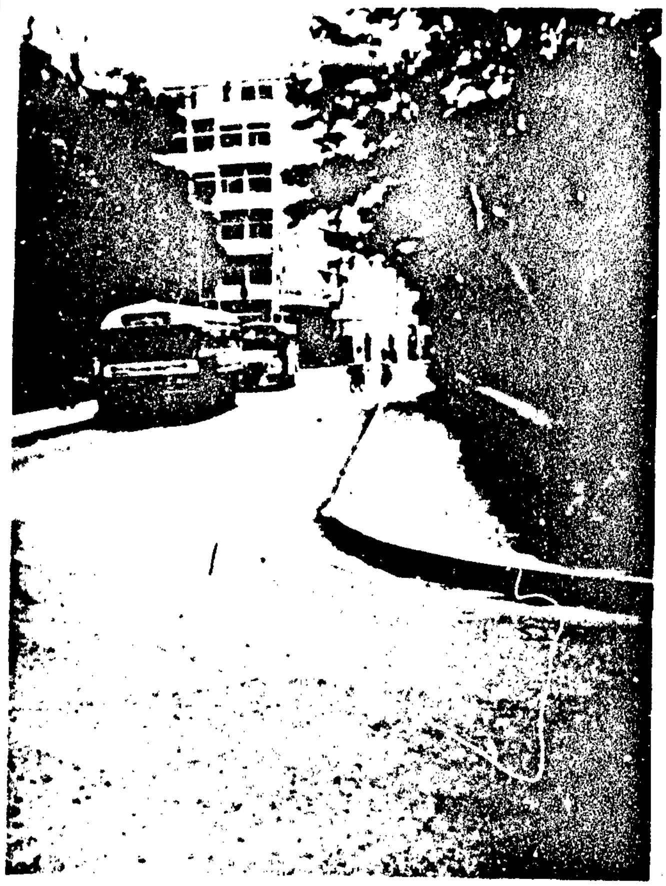


Figure 7

SAN JOSE STREET ACCESSIBLE TO MOTORIZED SWEEPERS

Other reasons for lost sweeper time are rain and time spent refilling the sweeper water-storage tank. The sweeping times are scheduled to avoid the rainfall hours. Because rainfall hours are usually short in duration and consistent from day to day, inclement weather occurs during only about 5 percent of the total 14-hour sweeping shifts. Approximately 7 percent of the time is spent refilling the water-storage tank.

Dump Trucks

Seven dump trucks are used in the current ceniza-arena cleanup operation, and two more are on order. The operational data shown in Table 2 are for three trips per loaded truck per day to dump areas outside the city and an average round trip of 10 miles.

Travel time to the dump is 20 to 30 minutes, depending on the distance and traffic conditions. The truck-loading time is usually 30 minutes to one hour, depending on the location of the ceniza-arena piles. If a truck load is in one dump pile, filling the truck with the front-end loader takes only a few minutes. If the truck must follow the loader to collect small dispersed piles, the loading takes longer. When several trucks are working with one loader that is moving about the streets in search of ceniza-arena piles, empty trucks returning from the dump often waste time finding the loader.

The average capacity of the trucks is 4 to 6 cubic yards. Quantitative data on ceniza-arena haulage is not readily available from the municipal figures, which give the number of truck trips and dumping locations but not the weight of the ceniza-arena carried each trip. Counting partially loaded trucks as full loads has undoubtedly led to overestimates of the total ceniza-arena removed from the city streets.

Front-end Loaders

Two front-end loaders are presently used with respective capacities of 1-1/4 cubic yards and 1/2 cubic yard (see Figures 8 and 9). The delivery of a third loader is expected soon. This third loader and two additional dump trucks will provide the more ideal ratio of three trucks per loader. The current excess of trucks has eliminated the loader standby time spent waiting for empty trucks.

The loader operators have had several years of experience operating heavy equipment plus 13 days of training on the job. Observation of the loading operations shows that operator skill is equal to that of

Figure 8

SMALL LOADER WORKING PILE OF CENIZA-ARENA MIXED WITH TRASH

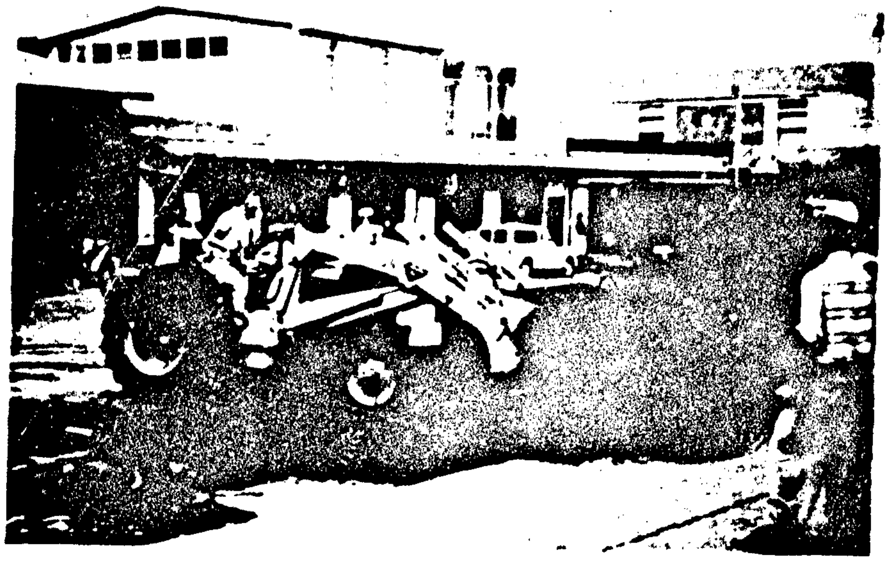
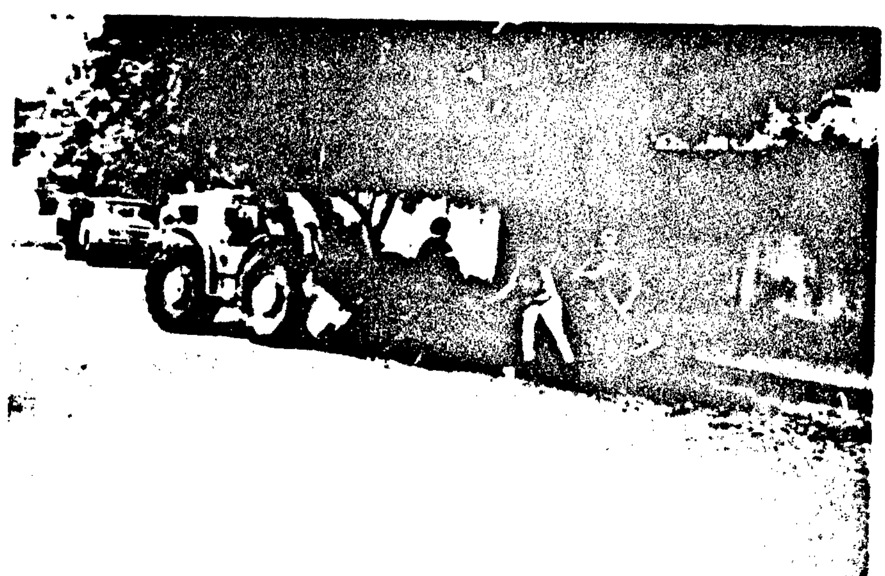


Figure 9

LARGE LOADER WITH MANUAL SUPPORT IN AREA OF RESTRICTED ACCESS



U.S. operators. Unusual loading operation skills are occasionally displayed in the loading of small ceniza-arena piles in confined spaces near trees. This is a capability not usually required of loaders, which are designed to move large gravel or dirt piles.

Three men with shovels provide support for the loader in getting the final portion of any ceniza-arena pile into the loader bucket (Figure 10). They also assist in loading tree limbs, scrap metal, and other unwieldy trash items that accumulate in the piles of ceniza-arena. Most residents of San José apparently observe no distinction between ceniza-arena and trash removal, although separate trash pickup is provided by the city. Figure 11 shows a typical ceniza-arena and trash pile.

Figure 10

MANUAL SHOVELING INTO LOADER BUCKET FOR FINAL CLEANUP OF CENIZA-ARENA PILE

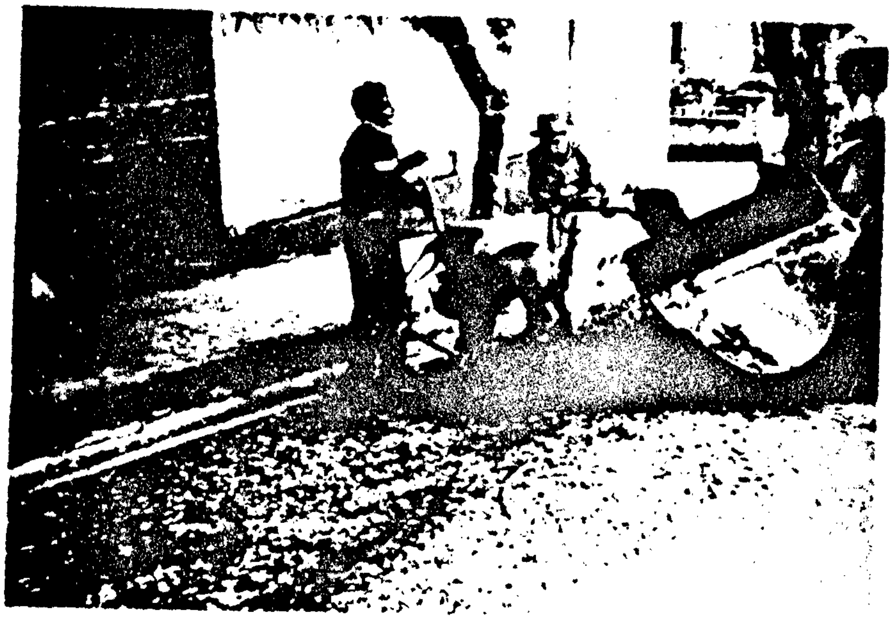
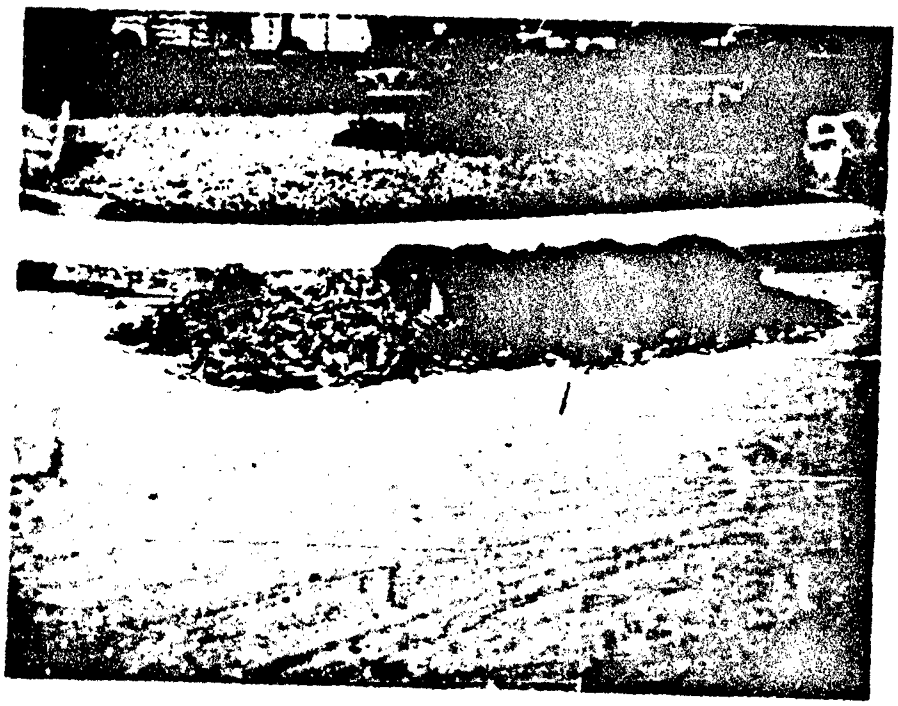


Figure 11

TYPICAL CENIZA-ARENA AND TRASH PILE



IV MANUAL CLEANUP

The ceniza-arena located in places not accessible to mechanized equipment is removed by manual methods. Before the present mechanized equipment was in use, about 400 men with wheelbarrows, brooms, and shovels did most of the cleanup work in the city. About 100 men now handle special jobs such as cleaning catch basins and streets on which the sweepers cannot be operated. Manual cleanup is usually done on the 8-hour shift from 6 a.m. to 2 p.m. The manually gathered ceniza-arena is placed on existing dumps or piled at the curb in the middle of the block at two-block intervals for later pickup by the front-end loaders.

Roofs and Gutters

The cleaning of roofs and roof gutters, except for government buildings, is the responsibility of the individual property owner. There is no roof-cleaning schedule, and owners dump the ceniza-arena from roofs into the street or into trash cans at their convenience. City efforts have been unsuccessful in regulating private dumping of ceniza-arena into the streets to coincide with city collections in the area.

The slope and smooth surface of the corrugated iron roofs are usually such that the wind or rain moves the deposited ceniza-arena to the roof gutter. Existing roof gutters are of small cross section (4 inches wide and 2 inches deep) with roof overlap that makes them difficult to clean by hand. However, the new replacement gutters usually have a larger cross section (8 inches wide and 6 inches deep) for easier access with hand scoops to remove the wet or dry caked ceniza-arena. Wet ceniza-arena is removed from the gutters by hand scoops and is then placed into buckets for transport to the ground with the use of a ladder or with a rope attached to the bucket. The dry ceniza-arena is removed also by the hand scoops with transfer to buckets or to a pipe chute that leads to a barrel on the ground. One enterprising entrepreneur has set up a roof-cleaning business using a system equipped with a vacuum cleaner that collects the ceniza-arena in a barrel placed on the sidewalk.

Most roof gutters are drained by downspouts that descend vertically on or within the walls of buildings to tunnels under the sidewalk and through the curb to the street storm drains. As might be expected, the downspout system is easily plugged with ceniza-arena particles.

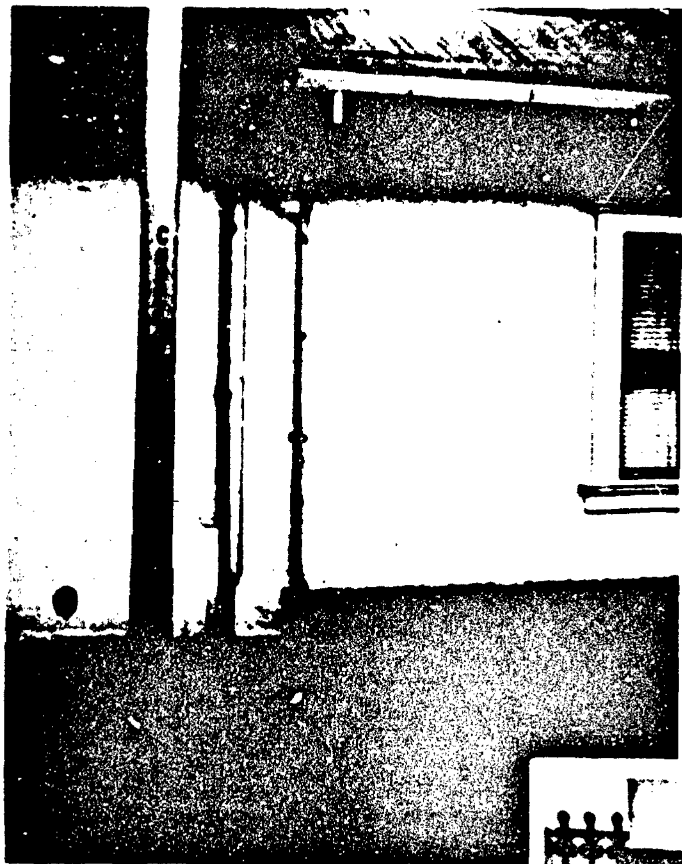


Figure 12

NEW LARGE CROSS SECTION ROOF GUTTER AND DOWN-SPOUT SYSTEM TO STREET; OLDER, SMALL GUTTER ON LEFT

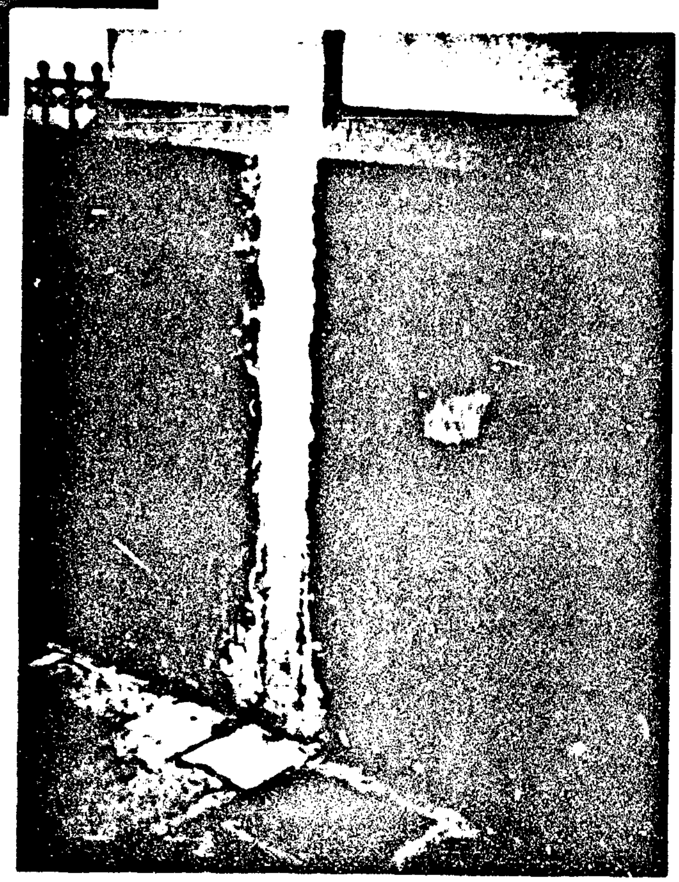


Figure 13

NEWLY INSTALLED DOWN-SPOUT IN WALL WITH CLEANOUT AT BOTTOM

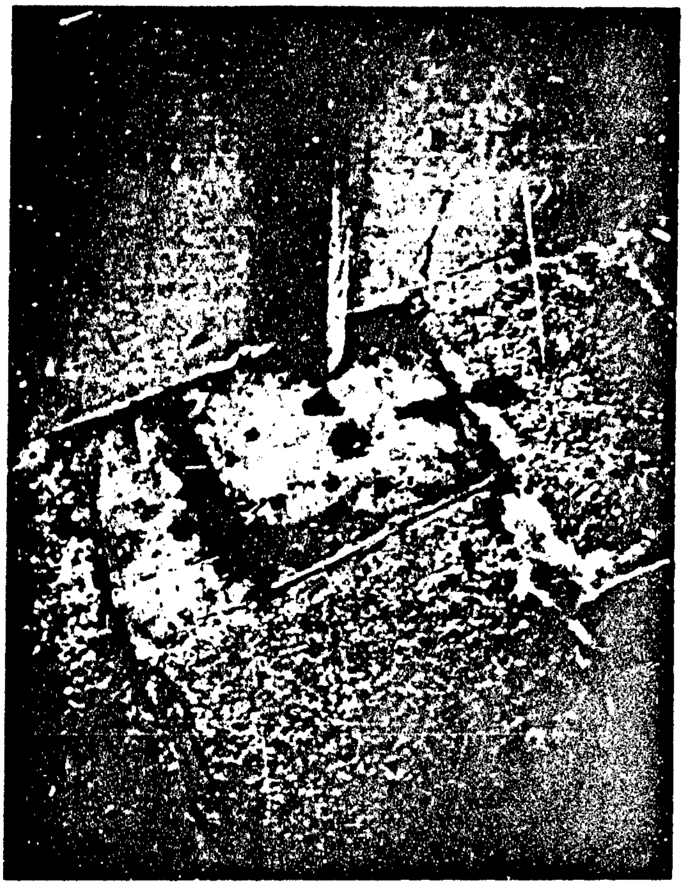


Figure 14

REMOVABLE SIDEWALK BLOCK FOR DOWNSPOUT CLEANOUT

'igures 12, 13, and 14 show new roof-gutter and downspout installations .nd steps taken to alleviate the clogging problem.

The frequency of roof-gutter cleaning necessary to keep them clear .epends mostly on the rainfall conditions. Gutters are seldom cleaned uring the dry season, not only because the ceniza-arena contained is 'elatively sparse and is not cake hardened, but also because people are nclined to wait until the need to clean is self-evident. During the ›eriods of light rain, they are cleaned once a month. When it rains ›eavily and frequently, most of the ceniza-arena deposited upon the roof s washed to the gutters before it can be carried away by wind, and ›iweekly cleaning is necessary to prevent the gutters from being caked o capacity.

›idewalks

Sidewalk cleaning also is the responsibility of the individual ›roperty owner. The ceniza-arena is generally swept into the gutter with . handbroom. Figures 15 and 16 show ceniza-arena deposits on smooth and

rough sidewalks in sections of the city where owners did not clean their walks. The employees in downtown stores sweep their sidewalks frequently to prevent people from tracking the ceniza-arena inside the store. Observed cleaning times for sidewalks averaged about 40 seconds per square meter.

Storm Drains

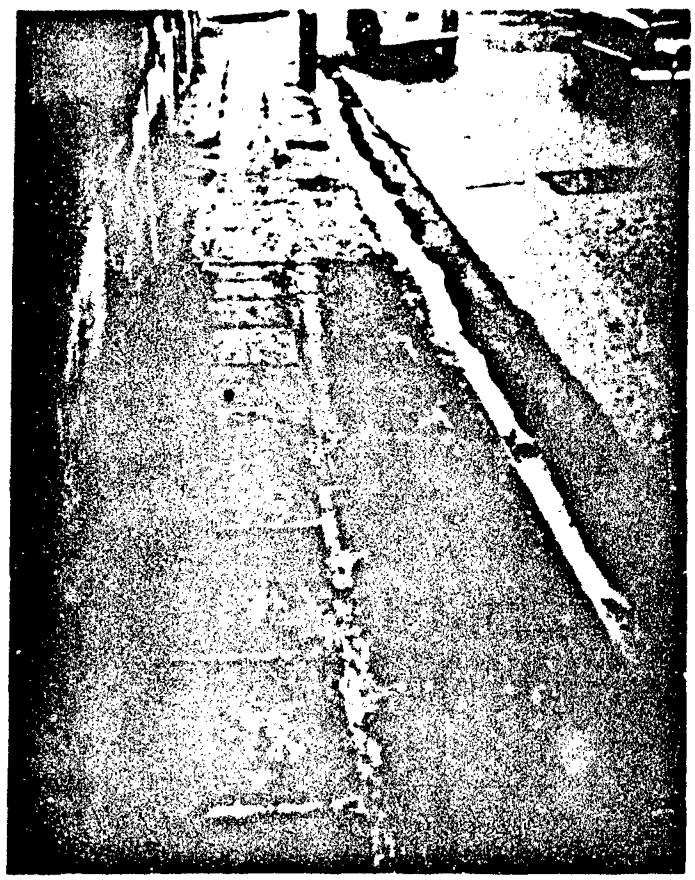
The city of San José has an extensive storm-drain system to handle the annual 70- to 80-inch rainfall. Without the ceniza-arena, the normal accumulation of coarse trash in the catch basins does not offer a serious stoppage problem. However, when the ceniza-arena is added to the trash, it fills all the small spaces in the usual trash to form an impervious dam. It appears that neither trash nor ceniza-arena alone poses a serious drain-stoppage problem, but combined they cause stoppages that necessitate considerable drainage maintenance. This observation is based on the fact that most of the catch basins handled the ceniza-arena alone without stoppages and the drainage pipes did not become clogged.

During the rainy season, cleanup of the clogged catch basins is done on a demand basis. Policemen and other civic-minded people report clogged drains to the sanitation department, which then dispatches a "vac-all" unit to the site. The "vac-all" (Figures 17 and 18) is a commercially available truck-mounted vacuum system, with a 10-inch suction pipe and a storage tank, designed for cleaning water-filled catch basins. After manual scraping has loosened the ceniza-arena and dislodged the coarse trash in a catch basin, the "vac-all" takes about an hour to clean it.

All the storm-drain basins that were examined have the outlet pipe flush with bottom of the basin. This does not allow space for such heavy material as ceniza-arena to settle, thereby reducing the quantity entering the outlet pipe; such a space could easily have been provided had the current accumulation of ceniza-arena been anticipated.

Figure 15

CENIZA-ARENA DEPOSIT ON SMOOTH SIDEWALK AFTER REDISTRIBUTION BY WEATHER, PEDESTRIANS, AND VEHICL-ULAR TRAFFIC

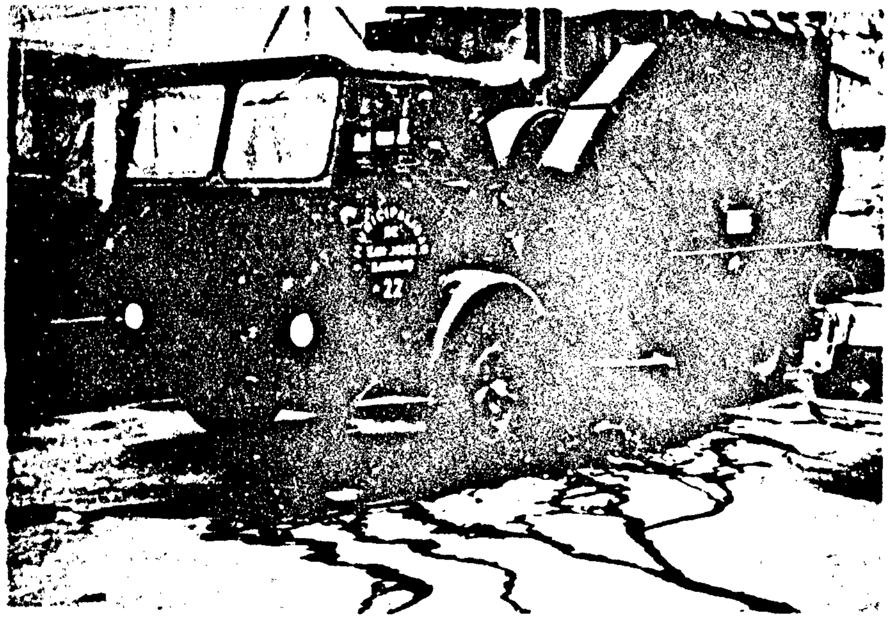


igure 16

ꓷUGH SIDEWALK DIFFICULT ꓷ SWEEP WITH HANDBROOM

Figure 17

MOBILE VACUUM SYSTEM FOR CLEANING CLOGGED CATCH BASINS



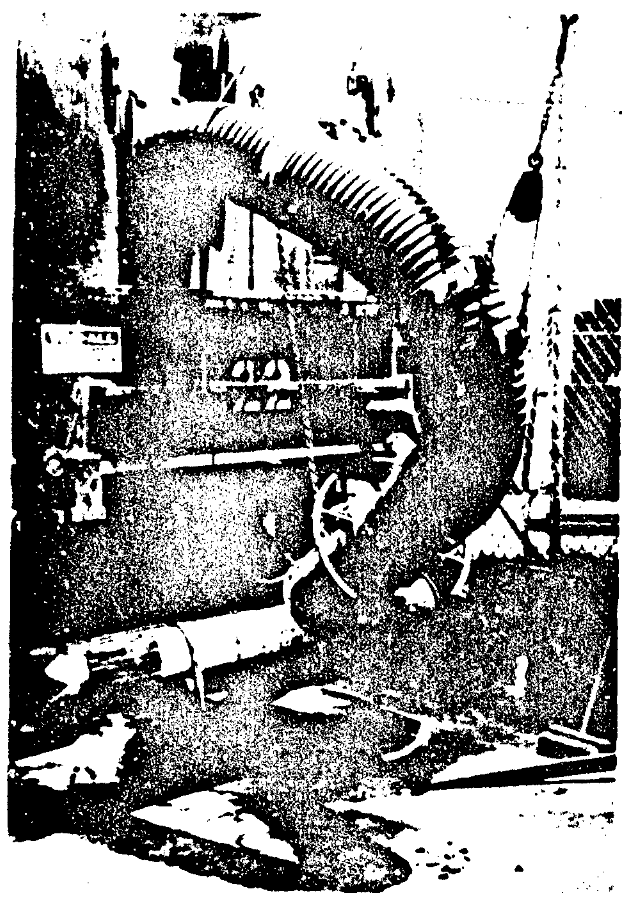


Figure 18

REAR VIEW OF MOBILE VACUUM SYSTEM SHOWING HYDRAULICALLY ADJUSTABLE SUCTION NOZZLE

V STATISTICAL DATA ON CENIZA-ARENA DEPOSITION AND REMOVAL

Basic data on the amount of ceniza-arena deposited in San José, the .lage of ceniza-arena and trash to the dump area, and local rainfall · tabulated in the Appendix. Table 3, derived from the same data, marizes the information on the ceniza-arena deposition and removal. data for the three-month period May 1 to August 1, 1964, was used to .imize the effects of variations in the scheduled cleanup procedure, ch may or may not correlate with daily deposit data. This summary uld show reasonable material balance relationships between the amount ceniza-arena deposited in the city and the amount removed in the clean- operations. However, the tabulations indicate inconsistencies among data; some of these discrepancies are explained in the following agraphs.

To assess the ceniza-arena cleanup effectiveness, the ceniza-arena oval and haulage must be compared with the amount deposited. The iza-arena deposition levels were measured in the Meteorological titute headquarters in the eastern part of San José. Although ceniza- na deposits, like rain showers, can be quite localized at a given e, measurements over a longer period of time should tend to average over an area no larger than the central section of the city. Some ferences from east to west might be expected to persist owing to ying distance from the volcano. If the ceniza-arena deposition dient with distance were comparable to the fallout from a 5- to 10-KT lear weapon,* as the cloud dimensions indicate, and if an idealized stant wind pattern existed, the deposit levels at the western edge the city (18 miles from crater) would be 40 percent less than the el at the Meteorological Institute headquarters (15.4 miles from the ter). With these reservations, the ceniza-arena deposit levels as sured at the Meteorological Institute have been assumed for the entire y for the purposes of the data analysis given in Table 3.

The municipal data specify two cubic meters as the amount of ceniza- na handled by the motorized sweepers at the time it is dumped. By

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lark, D. E., and W. C. Cobbin, Some Relationships among Particle ize, Mass Level, and Radiation Intensity of Fallout from a Land urface Nuclear Detonation, USNRDL-TR-639, March 21, 1963.

Table 3

CENIZA-ARENA DEPOSITION, SWEEPING, AND HAULAGE DATA COMPARISONS
May 1, to August 1, 1964

Dump No.	Area Served (mi²)	Street* Swept (mi)	Street* Percent of Area	Deposit† (tons)	Ceniza-arena Handled: Sweeper‡ (tons)	Ceniza-arena Handled: Truck Haulage§ (tons)	Percent of Deposit Handled: Sweeper	Percent of Deposit Handled: Truck
1	0.106 mi²	3.67 mi	15.1%	1,870 t	77 t	1,281 t	4.1%	68.5%
2	0.051	1.58	13.5	902	0	115	0	12.7
3	0.091	1.98	9.5	1,610	18	293	1.1	18.1
4	0.053	1.44	11.8	937	15	15	1.6	1.6
5	0.028	0.74	11.5	495	5	7	1.0	1.4
6	0.036	0.92	11.1	636	7	100	1.1	15.7
7	0.040	0.87	9.5	707	123	978	17.3	138.3
8	0.054	1.40	11.2	955	19	1,138	1.9	119.1
13	0.048	1.37	12.4	849	40	1,571	4.7	185.0
14	0.060	1.63	11.8	1,060	37	1 557	3.4	146.8
15	0.038	1.22	14.0	672	51	349	7.5	51.9
16	0.043	1.64	16.6	760	9	138	1.1	18.1
17	0.042	1.22	12.6	743	36	17	4.8	2.2
18	0.055	1.93	15.3	972	36	48	3.7	4.9
19	9.931	1.09	15.3	548	26	34	4.7	6.2
20	0.014	0.38	11.8	248	23	233	9.2	93.9
21	0.009	0.35	16.9	159	0	0	0	0
22	0.039	1.07	11.9	690	14	20	2.0	2.8
23	0.091	2.23	10.7	1,610	4	14	0.2	0.8
24	0.009	0.43	20.8	159	26	69	16.3	43.3
25	0.032	0.79	10.7	566	10	854	1.7	150.8
26	0.049	1.39	12.3	866	2	252	0.2	29.0
27	0.034	1.12	14.3	601	0	148	0	24.6
29	0.074	1.79	10.5	1,310	37	102	2.8	7.7
30	0.186	3.18	7.4	3,290	37	62	1.1	1.8
31	0.058	1.55	11.6	1,030	66	47	6.4	4.5
Downtown**	0.662	21.30	14.0	11,700	1,057	5,567	9.0	47.5
Total and Average %	2.033 mi²	59.37 mi	12.7%	35,900 t	1,775 t	15,009 t	4.9%	41.8%

* For average street width of 7 meters.
† Based on uniform deposit of 568 7 g/ft² over the area.
‡ From sweeper capacity figures @ 1.76 tons/M³ .
§ From truck figures @ 1.76 tons/M³ .
**Central area served by dumps 9, 10, 11, 12, and 28.

Source: Stanford Research Institute.

measurement,* the bulk density of the ceniza-arena is 100 lbs/ft^3. With these figures, the sweeper load would be over 7,000 pounds, a weight far too great for the sweeper to carry. However, for lack of better data, these factors were used to estimate the weight of ceniza-arena handled by the motorized sweepers. The volume was converted to tons by a factor of 1.76 tons/m^3.

The municipal data apparently also overestimate the amount of ceniza-arena hauled by the trucks. The reported quantities of ceniza-arena hauled by the trucks are given in terms of the nominal truck capacities with no indication that a full load, by volume, was actually hauled and with no indications of the amount of trash that was mixed in with the ceniza-arena. As with sweepers, the volume of ceniza-arena, as given, results in a gross weight that is often in excess of the truck load capacity. One modifying condition, which affects the bulk density of the load in the truck, is that most loads are a mixture of trash, vegetation trimmings, and ceniza-arena. The resulting overestimate of ceniza-arena haulage, the fact that trucks serve extensive city areas beyond that covered by sweepers, and the added roof contributions, make it impossible to associate the truck haulage data with specific sweeper dump areas.

The respective percentages of ceniza-arena handled by sweepers and trucks (Table 3) give some indication of their effectiveness. In almost all cases, the sweeper did not handle the proportional share of the deposition that might be expected. The average of all areas shows that streets receiving 12.7 percent of the total deposition have only 4.9 percent of the deposition handled by sweepers. On the basis of the street deposition alone, this amounts to a gross effectiveness of only 38.5 percent. On the downtown area, a gross effectiveness of 64.3 percent for the sweepers was achieved. This does not imply that the sweeper effectiveness for any one pass approximated the percentages given and that the remaining corresponding percentage of material was left on the streets. If this were so, about 200 to 350 grams of ceniza-arena per square foot of street would be left behind on the streets, which certainly was not the case.

Small scale experiments have shown sweepers of the type used in San José capable of removing over 90 percent of the deposited mass from

*Miller, Carl F., et al., Operation Ceniza-Arena, Stanford Research Institute report in preparation.

pavements that are in good condition.* It would be expected that the streets in downtown areas would accumulate more than their proportionate share of ceniza-arena owing to redistribution from roofs and sidewalks with minimal losses to storm sewers. On the other hand, the apparent low removal effectiveness might be attributed to the inability to cover the entire street because of parked cars or to redistribution to unpaved adjacent areas by traffic and wind. The two 8-foot-wide sweeping passes along the curb leave the crown and center of the street unswept; however, passing traffic and wind cause most of the ceniza to migrate to the gutter. Other items contributing to decreased removal effectiveness of the sweepers are pavement roughness and the presence of curbings. A further apparent decrease in power sweeper effectiveness resulted from the treatment of the data. Manual cleanup reduces ceniza-arena deposits on streets that are swept by power equipment as well as on those that are not. The amounts picked up manually could not be determined and were tacitly assumed to be negligible; where, in fact, these amounts are significant and those removed by power sweepers are correspondingly lower, an apparent decrease in power sweeper effectiveness would result. Other areas, such as planting areas, private yards, and public parks, apparently were not cleaned at all and it was difficult to ascertain whether ceniza-arena migrated to or from these areas. Finally, an unknown amount of material is removed from the streets by the torrential afternoon rains.

In the final analysis, if the street sweepers only removed 38.5 percent of the 568.7 grams of ceniza-arena deposited per square foot of street, it would be desirable to know how and when the remainder was removed, and from the radiological standpoint, where it was redeposited. Unfortunately, this type of information has not been documented.

The percentage of the ceniza-arena deposits handled by trucks includes that handled by manual and motorized sweepers. Many of the truck haulage entries are more than 100 percent of the amount deposited. This is partially due to the inclusion of ceniza-arena collected beyond the defined areas, and the dilution of the loads with trash. Also, the haulage data for a given day may include collections of previously accumulated ceniza-arena on a given area.

Rainfall data collected over a ten-year period show 1964 to be a normal wet year (Table A-4). Normal rainfall generally occurs between

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* Clark, D. E., and W. C. Cobbin, Removal Effectiveness of Simulated Dry Fallout from Paved Areas by Motorized and Vacuumized Street Sweepers, USNRDL-TR-746, August 8, 1963.

1:00 p.m. and 7:00 p.m., and the cleanup schedule is arranged so that it is hindered very little by inclement weather. The relative effectiveness of motorized sweeping on wet as opposed to dry pavement was not determined, but since the streets do not stay wet for long and the sweeper sprinkler was used to suppress the suspension of dust, it may be assumed that differences, if any, are minimal. Wet pavements certainly did not hamper the rate of street sweeping.

VI COMPARISON OF CLEANUP OPERATIONS IN SAN JOSE AND POSTATTACK ENVIRONMENTS

Radiation dosage control is not one of the factors requiring consideration in the ceniza-arena cleanup operation of San José; however, the following conditions for ceniza-arena cleanup apply also to the physical removal of fallout:

1. A systematic cleanup plan to establish the area to be covered, dump locations, material handling equipment, routes to be followed, and all physical movement procedures.

2. Adaptation or training of personnel to carry out the systematic cleanup plan.

Consideration of the radiation dosage control factor would further complicate the scheduling and conduct of the cleanup operation. Perhaps the most important requirement for the radiological environment is the availability of an adequate operational plan. The present effective cleanup schedule in San José was evolved by trial and error over an extended time period and could be utilized as a point of departure in planning for postnuclear attack cleanup in the United States. In a radiological environment, however, the trial-and-error method for developing an operational schedule would not be acceptable. An effective dosage conservation program requires detailed preplanning and operational scheduling followed by preattack training.

A most important consideration in the establishment of an operational cleanup capability in a radiological environment is that a fairly large number of people would have to be trained and used because of radiation dosage control requirements. It is recalled that the average sweeper travel speed is three miles per hour and that 20.3 miles of street are swept by four sweepers within a six-hour period. The larger cities of the United States (over 25,000 population) have an average of only one sweeper per 40 to 50 miles of streets. At the rate of five miles of street for each six hours, about 50 to 60 hours of sweeping per sweeper would be required to sweep the streets of an entire city.

The environment in many U.S. cities after nuclear attack may not be suitable for the use of motorized sweepers on the streets. Debris in

lightly damaged areas or the presence of abandoned automobiles may make streets difficult if not impossible to sweep. In San José, the vehicular traffic causes redistribution of the ceniza-arena from the center of the streets toward the gutters. Because the streets are narrow, it is only necessary for the power sweepers subsequently to cover the curb lanes. In areas of U.S. cities left undamaged by nuclear attack, however, there will be little traffic to help distribute fallout toward the gutters. Although in time wind could cause the same type of redistribution, it is unlikely that in the case of wider streets the fallout would eventually be concentrated only on the curb lanes. Where distribution of fallout toward the gutters does not occur, or at least not to the extent caused by vehicular traffic in San José, the entire street width would require sweeping, which could easily triple the sweeping time mentioned above. In addition, more frequent dump cycles would be required, because dumping frequency would be based on the radiation dose rate from the accumulated fallout in the storage hopper rather than on its volume capacity.

Front-end loaders require manual support for picking up the remainder of large piles. To reduce dosage received by supporting personnel, the loader operator should work alone to dispose of the bulk of a large pile. Any fallout collected by hand shoveling should be dumped into an empty bucket. Excess trash may not be a problem, but debris might be.

Dump truck operations would have to be carefully planned for fallout haulage. Particular attention should be given to the selection of dump locations in view of the long term radiological hazards presented by nuclear weapon fallout. Routes to and from the dump as well as dosage to the truck driver must be considered.

Preplanning for cleaning during the rainy season of drainage systems from roof gutters to storm drains is important. San José experience shows that fallout can be the marginal addition to normal drainage debris that will clog the system. Continually maintained cleanliness of drainage systems may reduce or eliminate stoppage. A catch basin full of radioactive fallout would be extremely difficult to clean under most radiation dosage control criteria.

San José's ceniza-arena cleanup operation illustrates the magnitude of problems that could be involved in a decontamination effort following a nuclear attack. It also shows that the physical redistribution of fallout is an important factor in the selection of methods most suitable for such a decontamination effort.

Appendix

BASIC DATA FROM THE FIELD

Ceniza-arena deposit data* are presented in Tables A-1 and A-2.

Several hundred pages of ceniza-arena collection data on the use of the motorized sweepers and trucks were obtained from the records of the sanitation department of San José. Figure A-1 shows a typical record for motorized sweepers (barredoras) and Figures A-2 and A-3 are typical records for private and municipal trucks, respectively.

Table A-3 is a summary of the municipal records from April 29 to August 20, 1964. Using the descriptive information on the ceniza-arena collection locations, the quantities of ceniza-arena (cubic meters) were assigned to each of the 31 dumps shown in Figure 2. Decisions on assignment of ceniza-arena quantities to dumps in ambiguous cases were made on the basis of general knowledge of the cleanup procedure and patterns of operation as deduced during the summarizing of the data.

Monthly rainfall data for ten years, obtained from the San José Meteorological Institute, are presented in Table A-4. The measurements were made at the Meteorological Institute headquarters building located in the northeast part of the city at Central Avenue and 17th Street.

Table A-5 gives the land area (square miles) and total street length (miles), cleaned by the power sweepers, that each of the 31 dumps in Figure 2 serves. The areas and distances were measured on a 1:10,000 scale map of the San José metropolitan area. Because of the cleanup procedures used in the central area, dumps 9, 10, 11, 12, and 28 have been lumped together and designed "downtown."

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*Cumulative deposit since March 1963.

Source: Miller, Carl F., et al., Operation Ceniza-Arena, Stanford Research Institute report in preparation. Cumulative data before April 1, 1964, are from Tables I and II; data since April 1, 1964, are from continuous sequential exposure of two-foot-square aluminum trays with venitian blind (louver) inserts described in the same report.

Table A-1

CENIZA-ARENA DEPOSITIONS IN SAN JOSE

Sample Collection Time	Exposure Time (hrs)	Deposition (g/ft^2)	Accumulated Deposition (g/ft^2)
4/30/1400	--	--	1677.4 *
5/1/0800	18.0	0.49	1677.9
5/3/0800	48.0	10.94	1688.8
5/4/0800	24.0	13.65	1702.5
5/5/0800	24.0	10.92	1713.4
5/6/0800	24.0	8.00	1721.4
5/7/0800	27.0	10.45	1731.9
5/8/0800	21.0	9.04	1740.9
5/9/0800	24.0	11.88	1752.8
5/10/0800	24.0	19.82	1772.6
5/11/0800	24.0	26.56	1799.2
5/12/0800	24.0	22.10	1821.3
5/14/0930	25.5	35.81	1857.1
5/15/0930	24.0	5.69	1862.8
5/16/0850	23.3	5.69	1868.4
5/18/0900	48.1	16.69	1885.1
5/19/0830	23.5	18.58	1903.7
5/20/0815	23.8	8.24	1911.9
5/21/0900	24.7	3.19	1915.1
5/22/0830	23.5	0.45	1915.6
5/23/0730	23.0	0.53	1916.1
5/25/0900	49.5	2.92	1919.0
5/26/0800	23.0	0.16	1919.2
5/27/0815	24.3	1.69	1920.9
5/29/0830	24.3	1.85	1922.7
5/30/0800	23.5	Trace	1922.7
6/1/0900	25.0	0.10	1922.8
6/2/0845	23.7	0	1922.8
6/3/0900	24.3	0	1922.8
6/4/0845	23.7	0	1922.8
6/5/0845	24.0	0	1922.8
6/6/0800	23.2	6.31	1929.1
6/8/0845	24.8	6.58	1935.7
6/9/0900	24.3	0.93	1936.7
6/10/0840	23.7	0	1936.7
6/11/0900	24.3	0	1936.7
6/12/0930	24.5	0	1936.7
6/13/0900	23.5	0	1936.7

* Cumulative deposit since March 1963.

Source: Miller, Carl F., et al., Operation Ceniza-Arena, Stanford Research Institute report in preparation. Cumulative data before April 1, 1964, are from Tables I and II; data since April 1, 1964, are from continuous sequential exposure of two-foot-square aluminum trays with venitian blind (louver) inserts described in the same report.

Table A-1 (Continued)

Sample Collection Time	Exposure Time (hrs.)	Deposition (g/ft^2)	Accumulated Deposition (g/ft^2)
6/15/1445	53.7	28.23	1965.0
6/17/1240	46.0	14.94	1979.9
6/18/1145	22.9	16.15	1996.1
6/22/1200	96.2	55.75	2051.8
6/24/1340	49.6	3.11	2054.9
6/26/1320	47.7	8.38	2063.3
6/27/0945	20.4	4.93	2068.2
6/29/1210	50.5	59.52	2127.8
7/1/1300	48.8	9.81	2137.6
7/3/1400	49.0	6.98	2144.5
7/4/1200	22.0	6.36	2150.9
7/9/1030	118.5	66.60	2217.5
7/11/1230	50.0	2.22	2219.7
7/14/1200	71.5	1.69	2221.4
7/16/1025	46.4	0.36	2221.8
7/18/0930	47.1	1.45	2223.2
7/20/0830	47.0	0.94	2224.2
7/21/0830	24.0	0	2224.2
7/22/1230	28.0	0	2224.2
7/27/0850	116.3	0	2224.2
7/29/1000	49.2	11.40	2235.6
7/30/0900	23.0	7.27	2242.8
7/31/0935	24.6	1.71	2244.5
8/1/1045	25.2	1.57	2246.1
8/5/0945	95.0	28.07	2274.2
8/8/1000	71.8	18.17	2292.4
8/10/0800	46.0	5.69	2298.0
8/11/0800	24.0	7.49	2305.5
8/12/0815	24.2	22.32	2327.8
8/18/0800	143.8	18.83	2346.7
8/20/1045	50.7	1.51	2348.2
8/22/0800	45.3	10.25	2358.5
8/24/0800	48.0	1.90	2360.4
8/26/0800	48.0	5.58	2365.9
8/28/0900	49.0	3.04	2369.0
8/29/0900	24.0	3.87	2372.8
8/31/1000	49.0	6.45	2379.3
9/2/1200	50.0	0.50	2379.8
9/5/1030	70.5	8.78	2388.6
9/7/0830	46.0	15.12	2403.7
9/9/1000	48.7	1.40	2405.3
9/11/1000	48.7	1.40	2406.7

Table A-1 (Continued)

Collection Time	Exposure Time (hrs)	Deposition (g/ft^2)	Accumulated Deposition (g/ft^2)
9/12/1030	24.5	1.46	2408.2
9/14/0900	46.5	6.95	2415.1
9/16/1025	49.4	2.65	2417.8
9/18/1030	48.1	4.09	2421.9
9/22/0830	94.0	6.99	2428.9
9/23/1040	26.2	0.19	2429.1
9/25/0800	45.3	0.79	2429.8
9/28/1045	74.8	0	2429.8
9/30/1000	47.2	0	2429.8

a. Cumulative deposit since March 1963 from Ref. 1

Table A-2

MONTHLY DEPOSITION RATES FOR THE ACCUMULATION OF CENIZA-ARENA IN SAN JOSE

Year	Month	Monthly Deposition g/ft^2	Accumulated Deposition g/ft^2
1963	March	16.3	16.3
	April	141.3	157.6
	May	67.3	224.9
	June	32.7	257.6
	July	153.1	410.7
	August	57.2	467.9
	September	3.6	471.5
	October	14.9	486.4
	November	91.3	577.7
	December	450.9	1,028.6
1964	January	355.0	1,383.6
	February	55.9	1,439.5
	March	64.1	1,503.6
	April	173.8	1,677.4
	May	245.4	1,922.8
	June	214.8	2,137.6
	July	108.5	2,246.1
	August	133.2	2,379.3
	September	50.5	2,429.8

Source: Miller, Carl F., et al., Operation Ceniza-Arena, Stanford Research Institute report in preparation. Cumulative data before April 1, 1964, are from Tables I and II; data since April 1, 1964, are from continuous sequential exposure of two-foot-square aluminum trays with venition blind (louver) inserts described in the same report.

Figure A-1

TYPICAL MUNICIPAL RECORD OF MOTORIZED SWEEPER (BARREDORAS) ACTIVITY

257-SSM-64

No

MUNICIPALIDAD DE SAN JOSE

COSTA RICA - APARTADO 5102

12 de agosto de 1964

Señor
Ing. Manuel A. Padilla J.
Jefe Dirección Técnica
S. O.

Estimado señor:

Le rindo informe correspondiente a la labor realizada por unidades barrederas de esta Sección durante el día 5 de los corrientes en el barrido de calles:

MAQUINA Nº Y HORA	Nº VIAJES	Nº M3 BAS
BARREDORA Nº 53- AVENIDAS 7-3-1-26- DE CALLE 14 a 15 Y AVENIDAS 4-5 DE CALLE 9 A 14 , AVENIDA CENT DE CALLE 14 a 23	3	6
BARREDORA Nº 53- 11 p.m. a 5 a.m. DE CALLE CENTRAL A CALLE 11 Y DE AVENIDA 7 A LA 18, LUEGO CALLE 13 AVENIDA CENTRAL A 2 Y CALLE 15 DE AVENIDA 2 A 7	3	6
BARREDORA Nº 53- 7 a.m. a 3 p.m. DE ESCALANTE	4	8
BARREDORA Nº 54-	3	6
BARRIOS LINCON EN SAN FCO Y CIUDADELA EL SEGURO EN ZAPOTE	3	6
BARREDORA Nº 52- BARRIOS LOS SAUCES Y JARDINES DE CARVAJAL	1	2
TOTAL	17 v.	34 m3

Atentamente,

Alvaro Gómez Alfaro
INGENIERO JEFE SECCION
DE SANIDAD MUNICIPAL

Figure A-2

TYPICAL MUNICIPAL RECORD OF CENIZA-ARENA HAULING BY PRIVATELY OWNED TRUCKS

MUNICIPALIDAD DE SAN JOSE
COSTA RICA - APARTADO 5107

No. [illegible]

1964 MAY 29 AM 10:03

27 mayo 1964

Señor

Ing. Manuel A. Padilla J.

Jefe Dirección Técnica Municipal

S. D.

Estimado señor:

Me permito rendirle informe de la recolección de ceniza efectuada por vehículos particulares durante el día 26 de los corrientes:

VEHICULO Nº	CANTIDAD		PROCEDENTE DE:
10544	4	M3	Av. 14 Cas. 7
10544	4	M3	Zapote
10544	4	M3	Av. 22 Cas. 1
10544	4	M3	Bº El Carmen
10544	4	M3	Bº El Carmen
10544	4	M3	Plaza Víquez
10544	4	M3	Ca. 5 Av. 10
10544	4	M3	Dos Ríos
10544	4	M3	Hatillo
10544	4	M3	Bº Méjico
10544	4	M3	Bº Méjico
10544	4	M3	Hatillo
TOTAL	48	-	
10086	4	M3	Ca. 9 Av. 8
10086	4	M3	La Pitahaya
10086	4	M3	La Pitahaya
10086	4	M3	Av. 18 Ca. 1
10086	4	M3	Av. 20 Ca. 9
10086	4	M3	Av. 22 Ca. 1
10086	4	M3	Av. 18 Ca. 19
10086	4	M3	Av. 2 Ca. 5
10086	4	M3	Ca. 25 Av. 14
10086	4	M3	No tiene dirección
TOTAL	40	-	

PASA A LA PAGINA Nº 2

Figure A-3

TYPICAL MUNICIPAL RECORD OF CENIZA-ARENA HAULING BY MUNICIPAL TRUCK

249-DDM-64

No._________

MUNICIPALIDAD DE SAN JOSE

COSTA RICA - APARTADO 5102

11 de agosto de 1964

2:08

12 AM 11:09

Señor
Ing. Manuel A. Padilla J.
Jefe Dirección Técnica
S. O.

Estimado señor:

Me permito informarle de la recolección de ceniza efectuada por unidades Municipales durante el día 6 de los corrientes:

UNIDAD Nº	CANTIDAD		PROCEDENTE			DE:
1576	5	M3	cas	11	avs	18/20
1576	5	m3	cas	Bº Nac. Unidas		
1576	5	m3	cas	15/17	avs	20
1576	5	m3	cas	19/21	avs	18
1576	5	m3	cas	15	avs	14
1574	5	m3	cas	15	avs	24
1574	5	m3	cas	Ciud. Calderón Muñoz		
1574	5	m3	cas	19/21	avs	18
1574	5	m3	cas	19/21	avs	18
1574	5	m3	cas	11	avs	12
1578	5	m3	cas	13	avs	28
1578	5	m3	cas	Bº Nac. Unidas		
1578	5	m3	cas	19/21	avs	18
1578	5	m3	cas	17	avs	14/16
1578	5	m3	cas	17/25	avs	10
1575	5	m3	cas	15	avs	24
1575	5	m3	Bº Vasconia			
1575	5	m3	cas	19/21	avs	18
1575	5	m3	cas	19/21	avs	14
SUBTOTAL	95	m3	con unidades de Vías Públicas			
1715	4	m3	cas	4	avs	16
1715	4	m3	cas	Urb. Finca Paso Ancho		
1715	8	M3	cas	Ciud. Nº 2 Hatillo		
1715	4	m3	cas	1/3	avs	2
1714	4	m3	cas	8	avs	18/20
1714	4	m3	cas	6	avs	16/20
1714	4	m3	cas	4	avs	10/12
1718	4	m3	cas	8	avs	12/18
1718	4	m3	cas	4	avs	14
1718	4	m3	cas	Finca Paso Ancho		
1718	4	m3	cas	Invu Nº 1 Hatillo		
1718	4	m3	cas	Invu Nº 1 Hatillo		

PASA

Table A-3

SUMMARY OF CENIZA-ARENA HANDLED BY MOTORIZED SWEEPERS (S) AND TRUCKS (T)
AT THIRTY-ONE ESTABLISHED DUMPS IN METROPOLITAN SAN JOSE
(CUBIC METERS - M^3)

Dump	1		2		3		4		5		6		7		8		9	
Date	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T
4/29		38.3				4						5						12
4/30		39			2	8	2					4	4	13		18		23
5/1		68.3											4	19		27		38
2		9											2	4				13
3													1					9
4				20		28							2			8		14
5																	3	
6		24.3												14				39
7		50				14.5						12	1	25		36		35
8		7			6	4	6					5	6	9		55	4	37
9		6														56.3		20
10	4														4			
11	36	50.5				6								29	2	40.3		28
12		29.5											4	13		7		28
13		19				7.3								22		20.5	4	56
14		46.3		7.3								4		16		52.3	9	63
15		73				43.8						9	8	20	6	32	2	
16		10					4		2		4		6					
17																		27
18		45.3				25						13	5	48		29	1	8
19		45.3		14.5		32						8.3	4	31		32	4	46
20		16				36						8	4	40		26		36.8
21		58				18						19	2	32	2	58		36
22		40.3				13						6	2	71.3		89	2	8
23		48.5				4								29		16		22
24													3		1		2	
25		66.5		14.5		5							1	13		17	1	12
26		19		8		41							4	7		14	4	21
27		46												7		30		27
28		15			1		2				2		2				2	15
29		72				11								32		16	2	6
30		21				4						16	3	10	2		2	24
31													4					
6/1																30		10
2	2												6	35		40	2	
3													4	20		45		
4	2												6				2	
5																		
6		20																9
7		5.5												5				

Table A-3 (Continued)

Dump	10		11		12		13		14		15		16		17		18	
Date	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T
4/29		16				28		45		21								
30		21			4	52		65.3		121.8		20						
5/1		7			6	20.5	1	45		44.8					1		2	
2		8	1	4	1	70.5	4	60.3		100	6			8				
3					6	20				49		20						
4	2	20		23	12	25		67.3		41.8								
5																		
6		38		4		39		63.3		12								
7		18	4	10	2	6		28.5		42		15		11.3			6	
8	2	14	4		4	31		96.5		47.3		10		14.5				
9		4				30.3		47		7.3		12		31.3				
10	4	15	10		9	7												
11		4	8	8	16	23.3		76		41		10		17				
12	1	16	9	55	3	56.3		54		49				11			5	6
13	4	38	8	4	14	60.3	1	55		14		29						
14		15	18	26	6	27		90.3	7	42.3	7							
15	2	32.5	5		6	49.5		62		51	18	25						
16	2	25		9.5	3			8		9.5								
17																		
18		12	1		2	18		34	7	45	7							
19		64		6	2	4	8	48		90			8					
20	2	11			3	41		88		25								
21		12	4	7	2	37.3		27.5		11.8					2		2	
22			2			6		54		58		30						
23		20				40.5		32		18								
24			8		6													
25		11		10	1	6		52		36								
26		24			2	6	6	125.5	4	18	6			4		4		13
27		8		10	3	18		19		81				4	2		1	
28				10	3													
29		4		14		24		62		40				4				
30		4		5	2	53.8	5	27.3		26.3				4		4		
31	2		2		4			10										
6/1										30		14						
2					2	25				75								20
3										30		55			3		3	
4		5		9.5		5												
5								25										
6						15			2		2				2		2	
7				5		4		10		15								

Table A-3 (Continued)

Dump	19		20		21		22		23		24		25		26		27 –	
Date	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T
4/29				15										50		114.8		20
30			4	39.8					2		2			6				
5/1	1			24			1							11		20		
2		6																
3														12				
4				21.8										46		6		
5																		
6				18										32		9		4
7										7.3				20.3				
8				7										13.3		22.3		5
9	4						4							14		11		
10																		
11														47.5		6		7.3
12														31		15		7.3
13				25										21		17		
14														48.3		5		
15														21.3				7.3
16																		
17																		
18				11										10				14.5
19				7								7.3		20.3				
20				7						7				28				
21	2		4	28										7.3				
22				33										30.3		6		
23				14										42				
24																		
25				7										18.3		10		
26				15										30		20		9
27	2													62		15		
28											6	7	6	8		6		
29			4	7										36				
30				8										27		16		12
31																		
6/1																		15
2													4					
3																		
4	2																	
5																		
6																15		
7	2										2							

Table A-3 (Continued)

Dump	28		29		30		31		Downtown	
Date	S	T	S	T	S	T	S	T	S	T
4/29		21		17		22				
30	1					40	4			
5/1	2								8	65.5
2	1	63		9					3	158.5
3	5								10	29
4	6	30							20	112
5									6	
6		69								189
7	9	20		9		2	20	40	15	89
8	6	38	7	9	8	10			20	120
9		48.8								103
10	12	23							35	45
11	41	25		4		4			74	88.3
12	23	77.3		7.3					36	228.5
13	10	60.3		13		12.3			40	218.5
14	24			3		3			57	131
15	14	54.8	9		9				29	136.8
16	7	15					8		12	49.5
17		37								64
18	7	51							11	89
19	8	44.8	2		2		2		14	164.8
20	15	72		13.3		2		7.3	20	160.8
21	14	69					4		20	161.25
22	2	39.5							6	53.5
23		10		2		2				92.5
24	21	55					6		37	55
25	3	84		4		4			5	123
26	2	59.8		4		4			8	110.8
27	3	38		2		2			6	101
28	5	10							10	35
29		30		17		17	2		2	78
30	6	29	3		2				10	91.8
31	2								8	
6/1										10
2	4	35							8	60
3	4								4	
4	2		2		2				4	19.5
5										
6	53									77
7	65									74

Table A-3 (Continued)

Dump	1		2		3		4		5		6		7		8		9	
Date	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T
6/8		20																
9														19		15	4	
10		15											2			63		
11	2	40											8					
12																		
13																		
14																		
15		10																
16													2				2	8
17													1				2	
18																	7	25
19		5								7			2			20		16
20		15													2		4	
21		10											7			17.5	10	
22													2				3	
23	3	10											3				1	40
24		9.5			3		2			3			1	20		10		9.5
25																		
26				9.5										32			0.5	24.5
27					8								2				0.5	14.5
28																	2	
29	10																1	80
30																		5
7/1		15											1			9.5	2.5	10
2	5	9.5											1				0.5	10
3	4	10											0.5					
4	9	12											0.5				1.5	
5		15											3				5	15
6		6.5														10		15
7		8		15														
8				15									1	9		9	2	
9													1					
10														15				39
11		15												20				
12														63		31	3	9
13																		
14														61		13		5
15														15		49	0.5	35
16																55	1	
17																14		14
18		36		5													2	
19																9		18
20																		
21																		
22		10																5
23		40														5		

Table A-3 (Continued)

Dump	10		11		12		13		14		15		16		17		18	
Date	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T
6/8				9		50		9.5	2	15		34						
9			2															
10					2			10										
11																		
12																		
13																		
14				25														
15				20														
16	7	2					4	7			3				2		4	
17						8												
18			5		2	30												
19	2		4	19.5	2													
20			4		6	20												
21					14	18		12										
22			0.5	35	0.5										2		2	
23	2				4	9.5	1											
24	2				2		3	8	3	58								
25	2				2		1											
26				10	1.5	10				15					2		2	
27	1.5	5	4.5		2		0.5	9.5	4	10		20						
28	9				10	15	1					40						
29			1		9.5			13										
30				39														
7/1					3													
2	1				1.5	20												
3	1			24.5	1.5	10			9						3		3	
4	2	10		10.5	3.5	9.5		15						9.5				
5	4				11			10						19				
6	1.5		10		1.5	9.5									1.5		1.5	
7	11	9.5	2	10	11	10			12									
8	2				9			9		10					10	9		9
9	3		4		6													
10	7		1.5		3					30		15						
11										70								
12	12	54		5	3	33				12								
13	3				3			20	6									
14					5	10		35	3	15								
15		10			1	5				20								
16	1			6	1	74				6								
17				6		50												
18					4	6									3		1	
19	1.5	4.8		30	15	36												
20						5												
21																		
22																		
23				27	1													

Table A-3 (Continued)

Dump	19		20		21		22		23		24		25		26		27	
Date	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T
6/8																		
9												15		59				57
10	2																	
11																		
12														30				
13																		
14																		
15																		
16		20	2															
17	4																	
18																		
19		8																
20																		
21			2															
22	2																	
23			2								6							
24																		
25											2							
26	1.5					1.5												
27																		
28																		
29																		
30			3															
7/1																		
2																		
3						2												
4																		
5															2			
6																		
7	3		5			3					2							
8																		
9																		
10																		
11																		
12																5		
13												10						
14																		
15											6							
16																		
17																		
18																4		5
19																		
20								15								9		
21								5				30		5		35		5
22														40				
23														36				

Table A-3 (Continued)

Dump	28		29		30		31		Downtown	
Date	S	T	S	T	S	T	S	T	S	T
6/8		24								83
9		10							6	10
10	2								4	
11		25					3			25
12										
13										
14										25
15		10								30
16	2	15					2		6	30
17	2	10							4	18
18		30							14	85
19	2	34							10	69.5
20	17	79							31	99
21		10							24	28
22	12	10	2		2				16	45
23	2	20					2		9	69.5
24	6	15							10	24.5
25	5		4		4				9	
26	6								8	44.5
27	3								11.5	19.5
28	8								29	15
29	6	35							17.5	115
30		10					3			54
7/1	1.5	10							7	20
2	6	10							9	40
3	3	20							5.5	54.5
4	3	20							10	50
5	4	34.5							24	49.5
6		25	5		5				13	49.5
7	20	40					5		44	69.5
8	8	35							21	35
9	35								48	
10	4	39.5							15.5	78.5
11		16	2		2		2			16
12		59							18	160
13	2	20							8	20
14	5						3		10	15
15	0.5								2	50
16	1								4	80
17		56								126
18	2	5							8	11
19	1	71							4	203
20										5
21										
22		9		5						14
23	1								2	27

Table A-3 (Continued)

Dump	1		2		3		4		5		6		7		8		9	
Date	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T
7/24				6										86				
25																		
26							1				1						1	
27								15						61.5				
28														10			1	
29																	1	24
30														15		30		25
31																		4
8/1					1.5		1.5		1.5		1.5			4				4
2																		
3						8							2					44
4																	1	56
5		10															1	12
6					3		5				2							
7						36		12					4					4
8	14												2	12				4
9													1					
10																		56
11									4								6	
12																5		20
13		82.5												16				4
14		18		12												50		4
15																		
16																		
17																		36
18														23		4		4
19						66								42				
20																48		

Table A-3 (Continued)

Dump	10		11		12		13		14		15		16		17		18	
Date	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T
7/24																		
25					2				1.5									
26	2				1		0.5											
27	0.5	24			2	4		4										
28	2				2.5			15	4	18								
29	5.5			10	1		4			29								
30			1							39			1					
31	2		2		2			27	2						2		1	
8/1	2	10	1	12.5	3								1		1			
2	4				3													
3	3	20			3													
4	1.5	16			1.5	30												
5	2		1		3	5	1		8				6		6		1	
6	6	9		5	4													
7	4	4			5	4	4		8	50								
8	3	4			3													
9	10				7													
10	4	18			4	30									4			
11						46	4		4	102								
12						45												
13		4				5												
14										36								
15																		
16																		
17		17		5		40		4										
18										32								
19		4						20										
20		6						12										

Table A-3 (Continued)

Dump	19		20		21		22		23		24		25		26		27	
Date	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T
7/24													22					
25																		
26																		
27			1						2		2							
28													15					
29													10					
30																		
31							2		2									
8/1	1																	
2			2															
3																		
4							2		2		2							
5	1															25		
6			2	8				10				15		55		5		
7																		
8																		
9																		
10																		
11	2						2											
12																		
13																		8
14																		
15																		
16																		
17																		
18																		
19																		
20										4				4				

Table A-3 (Continued)

Dump	28		29		30		31		Downtown	
Date	S	T	S	T	S	T	S	T	S	T
7/24										
25	5.5								9.5	
26	3		1		1				5.5	
27	4						1		8	28
28	7	5							16	5
29	2								4	34
30	2						2		3	25
31	8								14	4
8/1	4	8							10	34.5
2	11						2		18	
3	16								22	64
4			1.5		1.5				4	102
5		48							7	65
6	8	24		8		12	2		18	38
7	9	8							18	20
8	6								12	8
9	8								25	
10	12								20	106
11										
12										
13										
14										
15										
16										
17										
18										
19										
20		40								

Table A-4

SAN JOSE MONTHLY RAINFALL DATA

1955-1964

Month	1955 Inches	1955 Rainy Days	1956 Inches	1956 Rainy Days	1957 Inches	1957 Rainy Days	1958 Inches	1958 Rainy Days
January	0.01	2	1.04	8	0	0	0.20	4
February	0.09	2	1.39	2	0.16	2	0	0
March	0.18	6	0	0	1.06	4	0.56	5
April	0.15	3	0.38	5	0.34	2	1.25	3
May	5.09	17	13.55	30	8.80	23	6.18	20
June	13.28	23	11.52	23	5.08	19	11.65	24
July	14.02	28	9.85	22	5.30	18	7.23	22
August	8.15	22	7.28	19	6.52	20	6.94	22
September	16.38	29	10.15	25	13.81	25	9.62	26
October	19.08	28	15.43	26	11.53	29	10.46	23
November	6.00	22	5.26	19	0.81	15	3.33	15
December	2.13	14	1.44	11	0.85	7	0.57	7
Total	84.56	196	77.29	190	54.26	164	57.99	171

Table A-4 (Continued)

Month	1959		1960		1961		1962	
	Inches	Rainy Days	Inches	Rainy Days	Inches	Rainy Days	Inches	Rainy Days
January	0	0	0.09	3	0.01	1	0.12	3
February	0.08	3	1.63	8	0	0	0	0
March	0	0	1.11	3	0.05	1	0.05	1
April	1.11	2	3.58	12	0.44	7	1.87	11
May	5.30	14	14.27	22	2.03	11	7.70	21
June	13.57	27	8.42	24	7.92	25	13.20	27
July	6.67	18	10.54	24	8.26	23	6.85	18
August	7.06	21	7.49	21	5.04	19	12.16	26
September	4.54	18	10.21	27	20.37	27	17.07	27
October	10.01	26	16.21	29	11.43	22	16.24	31
November	3.49	16	5.24	18	3.88	19	6.02	20
December	0.08	2	0.64	9	2.11	12	2.28	12
Total	51.91	147	79.43	200	61.54	167	83.56	197

Table A-4 (Continued)

Month	1963 Inches	1963 Rainy Days	1964 Inches	1964 Rainy Days	1955-1965 Average Inches	1955-1965 Average Rainy Days
January	0.30	2	0.09	2	0.19	2.5
February	0.98	7	0.15	1	0.45	2.5
March	0.13	2	0	0	0.31	2.2
April	3.89	12	2.04	5	1.51	6.2
May	6.26	19	3.65	18	7.28	19.5
June	6.93	23	17.95	26	10.95	24.1
July	6.80	24	14.64	25	9.02	22.2
August	7.84	18	12.22	22	8.07	21.0
September	21.75	27	12.89	30	13.68	26.1
October	11.80	23			13.58	26.7
November	6.92	18			4.55	18.0
December	0.49	5			1.18	8.8
Total	74.09	180			69.40	179.1

Table A-5

LAND AREA AND LENGTH OF STREETS
SERVED BY ESTABLISHED CENIZA-ARENA DUMPS IN SAN JOSE

Dump	Land Area (mi^2)	Street Length (mi)
1	0.106	3.67
2	0.051	1.58
3	0.091	1.98
4	0.053	1.44
5	0.028	0.74
6	0.036	0.92
7	0.040	0.87
8	0.054	1.40
13	0.048	1.37
14	0.060	1.63
15	0.038	1.22
16	0.043	1.64
17	0.042	1.22
18	0.055	1.93
19	0.031	1.09
20	0.014	0.38
21	0.009	0.35
22	0.039	1.07
23	0.091	2.23
24	0.009	0.43
25	0.032	0.79
26	0.049	1.39
27	0.034	1.12
29	0.074	1.79
30	0.186	3.18
31	0.058	1.55
Downtown*	0.662	21.30
Total	2.033 mi^2	59.37 mi

* Central area served by dumps 9, 10, 11, 12, and 28.